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ERRORS IN VENTILATION.

By William Henry Thayer, M.D., Brooklyn, N. Y.

Carbonic acid is much heavier than atmospheric air. But the air expired from the lungs, with 8½ per cent of carbonic acid, is so much expanded by the animal heat that it is lighter than the atmosphere, and consequently rises to the ceiling.

It is a correct assumption that the reading public are sufficiently well acquainted with physical laws to render superfluous any restatement of their principles. One takes it for granted that his readers know the nature and actions of gases such as are found in the atmosphere. It is not supposed to be necessary to explain the common principles of ventilation. It would not have been necessary thirty years ago ; but since that time some erroneous views on this subject have been introduced, which are gaining credence not only with the general public, but also with some of those whose scientific education should have prevented the adoption of any fallacies.

The writer was much surprised to read in an article on ventilation contributed by R. Harvey Reed, M.D., of Mansfield, O. (*Annals of Hygiene*, October, 1890), the following sentence :

"The old method of putting a register at the top of the room for the escape of the foul air is neither economical nor scientific, and it wastes the heat, cools off the room, and leaves the cold, foul air as its legacy."

Correspondence with the author of this statement, during the winter of 1890 and 1891, elicited a confirmation of the same opinion, "that the cool air remains at the bottom of the room, with a large percentage of the foul air, or carbonic acid ; while the hot air, with a certain percentage of the carbonic acid, escapes at the top of the room or window."

The same writer read an elaborate paper to the Ninth International Medical Congress at Washington, September, 1891, on the subject of the Ventilation of Railway Cars, in which he proposes to have holes at the floor of the car, through which a downward current of cold air would carry off the carbonic acid gas which he supposes to have accumulated at the floor.

He proposes to bring in a current of warm air through the sides of the car, from a fire-box underneath the car. "By such a method," he says, "a constant supply of warm, pure air coming in at the sides of the car would soon heat it evenly all over, and by its presence would constantly drive the cold, foul stratum of air at the bottom of the car out through the foul air ventilators, . . . which should be placed at a level with the floor, and open into a foul-air conduit, which should pass out of the car, say, a foot above the top."*

Had this writer been alone in holding these views, it might not have been necessary to undertake publicly their correction. But there are many evidences that they have a certain prevalence, and are producing practical results which are injurious to health.

Thus, the Superintendent of Public Schools in Brooklyn says, "The system of ventilation prevailing in Brooklyn public schools is based on scientific principles. As is well known, hot air rises to the top, being more rarefied than cold air. Impure air, as it comes from the lungs, is denser than the ordinary atmosphere of a room, and descends. Consequently in school-rooms our system provides for the introduction of hot, pure air at the top, while the ventilating shaft to convey the impure air from the room is located low down in the room."†

And a New York building association, in a work on Modern Houses, says: "The hall should have a fireplace, not only for the sake of comfort and beauty, but for the reason that a

* Reports of the Ninth International Congress, vol. iv., p. 555. "Ventilation of Railway Cars." By R. Harvey Reed, M.D., Mansfield, O.

† The article in the Brooklyn *Eagle* of March 10th, 1891, from which this quotation is made, covers an interview with Superintendent of Schools W. H. Maxwell, held on account of a complaint made to the *Eagle* by a girl, a pupil of the Central Grammar School, that her marks had been cut down twenty per cent because of her maintaining the correct principles of ventilation, such as have been advocated in this paper. After the superintendent's opinions, already quoted, he goes on to say to the *Eagle*: "You will see from this that the young lady who wrote to the *Eagle* that she had been cut down twenty marks has no reason for complaint, if she answered the questions propounded without knowledge; and it looks as if she had."

It is unfortunate for Brooklyn schools that the superintendent is not a man qualified by education to advise in scientific matters; or, failing this, that he has not the discretion to avoid giving the weight of his official authority to decisions of which he is not a competent judge.

fireplace in the lower hall ventilates the whole house, more or less. The impoverished air from adjoining rooms and from the upper floors (bad air is heavy and descends) is attracted to it and carried off."

These views probably originated with Lewis W. Leeds, who published some lectures on ventilation in 1868, in which he advocated the making of outlets near the floor for the used-up air of a room, upon the ground that carbonic acid (CO_2) by its weight accumulates there ; and that it is therefore a mistake to have ventilating openings at the top. He says : "Carbonic acid is that much-dreaded poison in our breath, and the heavy portion of it [the breath] which causes it to fall to the floor."* He then illustrates his position by decomposing some scraps of marble by sulphuric acid upon the floor of a glass chamber, in which are lighted candles at different heights, and showing that the lowest is extinguished before the others, holds it proved that foul air in an inhabited room falls to the floor.

Such an experiment has no application to the conditions of the atmosphere of our rooms. Let us go back to the law of the diffusion of gases, discovered by Dalton, the celebrated English chemist, and published by him in 1803. Wyman says : "The discovery of this law has done much to establish the true principles of ventilation. Aëriform bodies possess the property of diffusing themselves through each other's masses to an unlimited extent ; there is no point at which they become saturated. Mr. Dalton filled two cylindrical vessels, the one with carbonic acid, the other with hydrogen ; the latter was placed perpendicularly over the former, and the two were connected together by means of a small tube two or three feet long. In the course of a few hours, hydrogen was detected in the lower vessel, and carbonic acid in the upper ; after a still longer time, these gases were found perfectly and equally mixed. Carbonic acid is more than twenty times the weight of hydrogen ; consequently the change of place was produced in opposition to the laws of gravity. This property belongs to all gases and vapors."†

* "Lectures on Ventilation." By Lewis W. Leeds, 1848, p. 15.

† "Practical Treatise on Ventilation." By Morrill Wyman, M.D., 1846, p. 12.

Dr. Wyman quotes two writers early in this century who published views on ventilation similar to those of Mr. Leeds, but the error was not repeated by any others until revived by Mr. Leeds. Those who err in opinion are led astray by knowing that carbonic acid is found almost pure in old wells that are shut up, and in the famous Grotto del Cane, in Italy; forgetting that in those situations it is formed in the soil, from which it is constantly pouring more rapidly than it can be diffused through the neighboring atmosphere.

We see that carbonic acid gas, although fifty per cent heavier than common air, will be gradually diffused through the atmosphere, at whatever temperature. In the case of the air that is expired from our lungs, surcharged with carbonic acid, it rises at once in an active current to the highest part of the room, because it is expanded by its higher temperature to greater lightness than the air of the room. From the neighborhood of the ceiling it is very gradually diffused through every part of the room, but remains in excess at the top as long as the supply continues. To sustain this proposition, I will quote from good authorities from the beginning of the century down to the present time.

Dr. Edward Turner, in his "Elements of Chemistry," says: "There is no real foundation for the opinion that carbonic acid can separate itself from the great mass of the atmosphere, and accumulate in a low situation, merely by the force of gravity."*

Dr. Neill Arnott, in his "Elements of Physics," says: "The air which a man has once respired becomes poison to him; but because the temperature of his body is generally higher than that of the atmosphere around him, as soon as he has discharged any air from the lungs, it ascends completely away from him into the great purifying laboratory of the atmosphere, and new air takes its place. . . . In a very close apartment ventilation must be expressly provided for by an opening near the ceiling, through which the impure air, rising from the respiration of the company, may pass away."†

Walter N. Hartley, in his "Air in its Relations to Life," says: "All the foulest air is near the ceiling; in fact, it is so

* "Elements of Chemistry." By Edward Turner, M.D., 1840, p. 189.

† "Elements of Physics." By Neill Arnott, M.D., 1848, p. 205.

bad there that unless an easy outlet be provided it becomes perfectly poisonous."*

In 1869 Dr. R. Cresson Stiles, Assistant Sanitary Superintendent of the Metropolitan Board of Health, made a Report on the qualities of the air of public buildings. He analyzed the air of public schools, hospitals, theatres, and churches, to ascertain the proportion of carbonic acid contained in it, and in some buildings measured the amount at different heights—near the floor and near the ceiling. His results varied with the different conditions of the rooms as to ventilation and air currents; but he says: "Air taken from near the ceiling was always found more highly charged with carbonic acid than that in the lower portions of a room, and the difference was often very marked. . . . In the hall of the Hamilton Literary Association, on the occasion of a meeting of the Kings County Medical Society, about eighty persons present, air taken within a foot of the ceiling, after three hours' occupation, gave 3.1 parts of carbonic acid per 1000, while that taken at the same time within three feet of the floor gave 1 part per 1000."†

I come now to the crucial test of the accuracy of those who expect to draw off the foul air from a building by outlets near the floor. The Church of St. Ann on the Heights, in Brooklyn, at the time of its construction, about twenty years ago, employed Mr. Leeds to ventilate it. He placed a pipe against the outer wall, running the whole length of the church on both sides, under the side galleries, about four feet from the floor, with an open grating in its whole length. These pipes are carried to the foot of the church tower, where they open into a perpendicular flue running up to the top of the tower, with ~~gas lights~~ steam pipes at the base to heat the air and aid in the upward current.

Dr. E. H. Bartley, Chemist of the Brooklyn Health Department, has kindly made analyses at my request of the air of St. Ann's at different heights, at a time when it was filled by the congregation. He writes:

* "Air and its Relations to Life." By Walter Noel Hartley, F.C.S., 1875. p. 108.

† Fourth Annual Report of the Metropolitan Board of Health, New York. 1869, p. 390.

BROOKLYN, February 21, 1892.

DEAR DOCTOR : The analysis of the air in St. Ann's Church this evening shows on the floor, under the edge of the gallery, 19 parts of CO_2 in 10,000 of the air, while on the gallery, immediately over the place where the first sample was taken, it shows about 40 in 10,000. Duplicate examinations taken on January 3d at the same hour—viz., at the close of the sermon, showed nearly the same results. These results show that the house is not well ventilated, and that, as would be expected, the CO_2 in the air in the gallery is much more than near the floor.

Very truly yours,

E. H BARTLEY, M.D.

The carbonic acid in the air of our rooms resulting from respiration, in the limited amount in which it exists after diffusion, is not the sole or the chief injurious and dangerous element of that atmosphere. The organic matters which are contained in the expired air are more prejudicial to health ; but as they are proportioned in amount to the accompanying carbonic acid, this gas " is taken as a convenient index to the amount of the impurities."*

The conclusion, from all the evidence adduced, is, that the carbonic acid gas of respiration and illumination will eventually be equally diffused through the atmosphere, although retained at the upper part of a room so long as the high temperature continues ; and that it never, under any circumstances, is precipitated in excess to the lower part of the room.

One's ordinary perceptions may be trusted for the extremes of atmospheric conditions of a room ; one perceives at once the difference between a very foul atmosphere and a very pure one. The Hall of the Brooklyn Institute—burned last year—when occupied, impressed one on entering as having a delightful atmosphere. It was about twenty-five feet high, and ventilated by large openings in the ceiling over two chandeliers. The only objection to such an arrangement made by well-informed people is the waste of heat. But when we take into consideration the immediate comfort and the prospective advantage to the health of the occupants, it is no waste ; it is a little more fuel, but it is a great deal less sickness.

* "Manual of Practical Hygiene." By Edward A. Parkes, M.D., 1883. p. 158.